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(54) Title: SUBSCRIBER LOOP EXTENSION SYSTEM FOR ISDN BASIC RATE INTERFACES

(57) Abstract

A system and method for reducing signal attenuation of integrated services digital network (ISDN) digital transmissions at the subscriber loop, thereby increasing the available subscriber loop range, is provided. An ISDN digital transmission system is used for transmitting and receiving digital information via a line termination at a central office. Customer premises equipment is coupled to a network termination (NT-1) within the customer premises, which is in turn coupled to interface the line termination at the central office. A plurality of inductive load coils are coupled in series with the two-wire subscriber loop ISDN BRI at predetermined distance intervals, which are calibrated to resonate the two-wire bus.

SUBSCRIBER LOOP EXTENSION SYSTEM FOR ISDN BASIC RATE INTERFACES

FIELD OF THE INVENTION

The present invention relates generally to digital telecommunications, and more particularly, to a system and method for reducing signal attenuation of integrated services digital network (ISDN) digital transmissions at the subscriber loop.

BACKGROUND OF THE INVENTION

The introduction of digital communications into the telephone network has greatly increased the available signal bandwidth. A corresponding reduction in the amount of cable required to carry a number of telephone conversations carried by analog telephony methods was also realized. The massive increase in the reliance and demand of telephone systems in today's society has driven the need for this reduction in cable and increased signal bandwidth.

A number of different technologies have been devised to facilitate the advance of digital communications. Various signaling technologies have used frequency division multiplexing (FDM) to segment the available bandwidth. Separate signals are carried in each segment using digital signaling derived through a digital representation of an analog waveform. Time-division multiplexing (TDM) has been used with T-1 and other transmission facilities, where each of a multiplicity of channels gets an interleaved time segment in order that all of the channels share the transmission medium equally.

A relatively newer and emerging field of telecommunications is the integrated services digital network (ISDN), which is a standard established by the International Telecommunications Union-Telecommunications (ITU-T-T) Standardization Sector. ISDN integrates computer and communications technologies to provide a common, worldwide, digital network. ISDN telephone lines use digital communications protocols allowing digital connections at up to 128 Kbps and as many as three separate conversations at the same time through the same line as the twisted-pair copper telephone line that traditionally carried only one voice, or one computer/fax communication.

One solution currently implemented in digital transmission lines is the use of repeater amplifiers in the long subscriber loops. Repeater amplifiers, however, are implemented at a cost of thousands of dollars per line. Furthermore, repeater amplifiers include active electronic devices, which decreases the field reliability of service and increases the cost of service maintenance. Another approach to lengthen the subscriber loop involves the use of non-standard transceivers at each end of the long loop, resulting in yet another costly installation.

Accordingly, there is a need in the digital communications industry for a transmission arrangement to increase the maximum subscriber loop reach which is inexpensive, easy to implement, and reliable. The present invention provides a system and method for reducing the loop loss on digital subscriber loops having component costs of only tens of dollars per subscriber line. Therefore, the present invention provides a low cost and reliable solution for reaching approximately 95 percent or more of potential digital communications customers without the use of active electronics coupled to the subscriber line. The present invention overcomes the aforementioned problems, and provides these and other advantages over the prior art.

SUMMARY OF THE INVENTION

The present invention is directed to a system and method for reducing signal attenuation of integrated services digital network (ISDN) digital transmissions at the subscriber loop, thereby increasing the available subscriber loop range.

In accordance with one embodiment of the invention, the present invention provides a integrated services digital network (ISDN) digital transmission system for transmitting and receiving digital information via a line termination at a central office. A customer premises having a plurality of terminal equipment devices is coupled to a first interface bus, and a network termination (NT-1) is coupled to the first interface bus within the customer premises. An ISDN interface is coupled to interface the line termination and the network termination (NT-1). The ISDN interface includes a two-wire bus, having a first connection for transmitting B-channel data of the ISDN interface, and a second connection for transmitting D-channel data of the ISDN interface. A plurality of inductive load coils are coupled

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

Figure 1 is a block diagram of an ISDN environment **100** in which the present invention applies. ISDN lines use digital, rather than analog, communications protocols. Within the customer premises **102** are various ISDN and non-ISDN terminal equipment devices. For example, an analog fax **104** and telephone **106** at the customer premises **102** are examples of communications devices at the customer premises **102** that are not ISDN-compatible. Such devices are coupled to a terminal adapter **108** which provides the ISDN interface at its output and an interface to the non-ISDN equipment at its input side.

ISDN-compatible equipment, referred to as terminal equipment (TE) includes, for example, computing device **110** as well as other ISDN-compatible user devices **112**. The terminal equipment **110**, **112**, and the ISDN-compatible output of the terminal adapter **108**, is provided to the network termination 1 (NT-1) **114** via the S/T interface **116**. ISDN terminal equipment devices, such as computing device **110** and user device **112**, are typically coupled to the network termination NT-1 **114** through a network termination 2 (NT-2) which provides additional services, such as switching or data multiplexing at the customer premises **102**. The S/T interface **116** is a 4-wire ISDN interface which can support multiple devices, and is a full-duplex interface including a pair of wires for received data, and a pair of wires for transmit data.

The NT-1 **114** is basically a termination between the customer and the service provider, which converts the 2-wire U-interface **118** at the local loop **120**. The NT-1 **114** can also provide status as to the condition of the ISDN line connection, as well as network performance and integrity checks. The local loop **120** includes the 2-wire U-interface **118** that interconnects network termination NT-1 **114** and a loop termination (LT) **122** at the central office **124**. The connection to other switches within the network, illustrated as the exchange switching equipment **126**, is referred to as the exchange termination function and occurs via the V-interface **128**.

The U-interface **118** provides the interface between the central office **124** and the various customer premises **102**. This connection typically runs under

represents a lumped inductance, shown as a toroidal inductor formed by providing conductor windings on an conductive core, which simulates a distributed inductance over the U-interface **118**. The load coil **300** is interleaved into the U-interface **118** in order to resonate the line thereby reducing the attenuation on the U-interface **118**. As will be described below, this allows the local subscriber loop **120** to be increased while maintaining the integrity of the transmitted digital information.

Referring now to FIG. 4, a more specific embodiment of a U-interface **400** is provided. The U-interface **400** is a 2-wire interface including lines **400a** and **400b**. A plurality of load coils **402**, **404**, and **406** on line **400a**, and a plurality of load coils **408**, **410** and **412** on line **400b** comprise the inductance loading of the ISDN interface **400** illustrated in FIG. 4. The load coils on each line are in series, separated by a distance d represented by dimension lines **414** and **416**. It should be recognized that a greater or lesser number of inductance load coils can be used on lines 400a and 400b, as will become readily apparent in accordance with the following description.

The twisted-pair U-interface **400** has inherent distributed transmission line parameters for wires having certain physical and electrical characteristics. For example, the standard copper wire used for the U-interface **400** can be calculated depending on the diameter of the wire used. This is based on the resistance, inductance, capacitance and conductance per mile for each of the standard wire gages at various temperatures and frequencies. The load coils **402-412** act to resonate with the distributed capacitance on the transmission line to provide a low pass filter effect. The resonant frequency is inversely proportional to the square root of the inductance times the capacitance as shown in equation 1 below:

$$f_R = \frac{1}{2\pi\sqrt{(L \times C)}} \qquad \text{[Eq. 1]}$$

where f_R is the resonant frequency;

L is the inductance of the line; and

C is the capacitance of the line.

decrease in loop attenuation of approximately 15dB near 40 Khz. This decrease can be seen by the distance depicted on line 600 between the original waveform 602 and the loaded waveform 604.

Figure 7 is a graphical diagram illustrating the insertion loss versus frequency for a range of inductance load coil values for AWG24 cable in accordance with one embodiment of the present invention. Waveform 700 represents the signal corresponding to a line loaded with 820 microhenries of inductance at 3,000 feet spacings. Waveform 702 illustrates how the resonant frequency is decreased as the load inductance increases, as waveform 702 corresponds to a line loaded with 1000 microhenries of inductance at 3,000 feet spacings. Analogously, waveform 704 illustrates how the resonant frequency increases as the load inductance decreases, as waveform 704 corresponds to a line loaded with 680 microhenries of inductance at 3,000 feet spacings. This illustrates the variance of insertion loss using different inductance loading values.

It will, of course, be understood that various modifications and additions can be made to the preferred embodiments discussed hereinabove without departing from the scope or spirit of the present invention. Accordingly, the scope of the present invention should not be limited by the particular embodiments discussed above, but should be defined only by the claims set forth below and equivalents thereof.

6. The ISDN digital information transmission system as in Claim 1, wherein the inductive load coils comprise inductors having a value of approximately 820 microhenries, and wherein the predetermined distance intervals are each approximately 3000 feet.

7. The ISDN digital information transmission system as in Claim 1, wherein an inductance value of the inductance load coils and the predetermined distance intervals are selected so as to resonate the two-wire bus at a frequency approximately centered on a frequency spectrum for 2B1Q signaling for an ISDN basic rate interface.

8. The ISDN digital information transmission system as in Claim 1, wherein an inductance value of the inductance load coils and the predetermined distance intervals are selected so as to resonate the two-wire bus at a frequency of approximately 40,000 Hz.

9. The ISDN digital information transmission system as in Claim 1, wherein the plurality of inductive load coils comprises:

(a) first inductive load coils coupled in series to the first connection at predetermined distance intervals; and

(b) second inductive load coils coupled in series to the second connection at the predetermined distance intervals.

10. The ISDN digital information transmission system as in Claim 1, wherein the plurality of inductive load coils comprises a plurality of dual-input/dual-output load coils each coupled to both of the first and second connections at common locations along the two-wire bus.

11. The ISDN digital information transmission system as in Claim 1, wherein the customer premises further comprises:

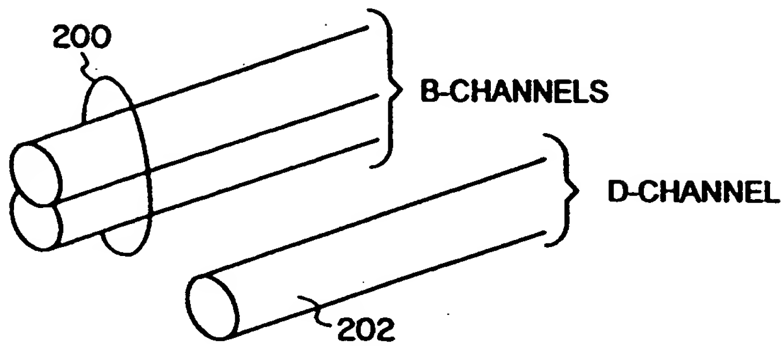
(a) a plurality of analog communication devices;

modulating the digital information at a frequency substantially equivalent to a center of a frequency spectrum for digital transmitters/receivers communicating the digital information;

transferring the digital information through one or more localized inductors which together approximate a distributed inductance; and

calibrating the localized inductors to provide a distributed inductance to resonate lines on a local loop between the customer premises and the central telephony office at the frequency corresponding to the center of a frequency spectrum.

BASIC RATE INTERFACE



PRIOR ART

FIG. 2

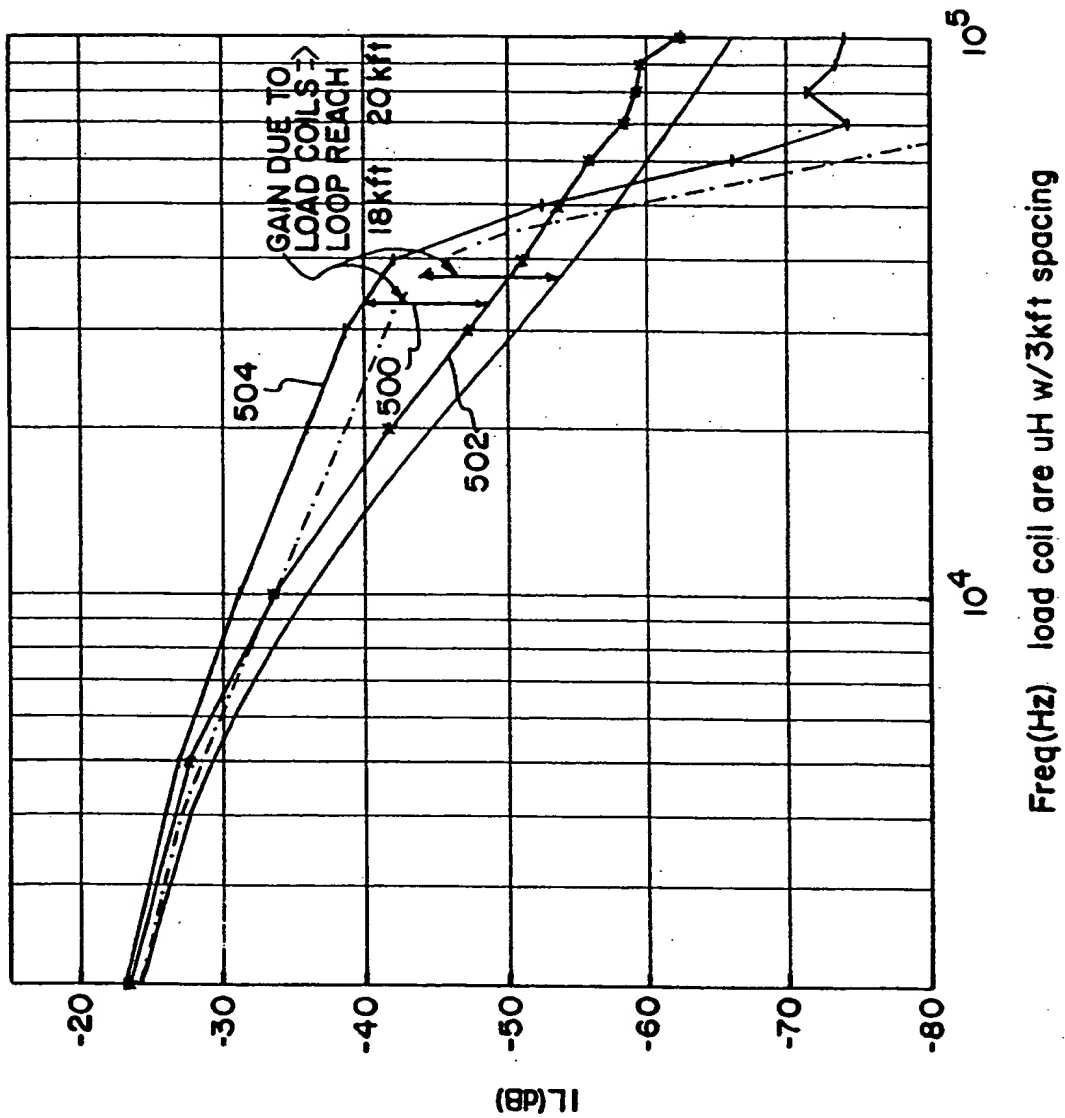

GAIN DUE TO
LOAD COILS ⇒
LOOP REACH
18kft 20kft
504
500
502
-20
-30
-40
-50
-60
-70
-80
IL(dB)
10^4
10^5
Freq(Hz) load coil are uH w/3kft spacing

FIG. 5

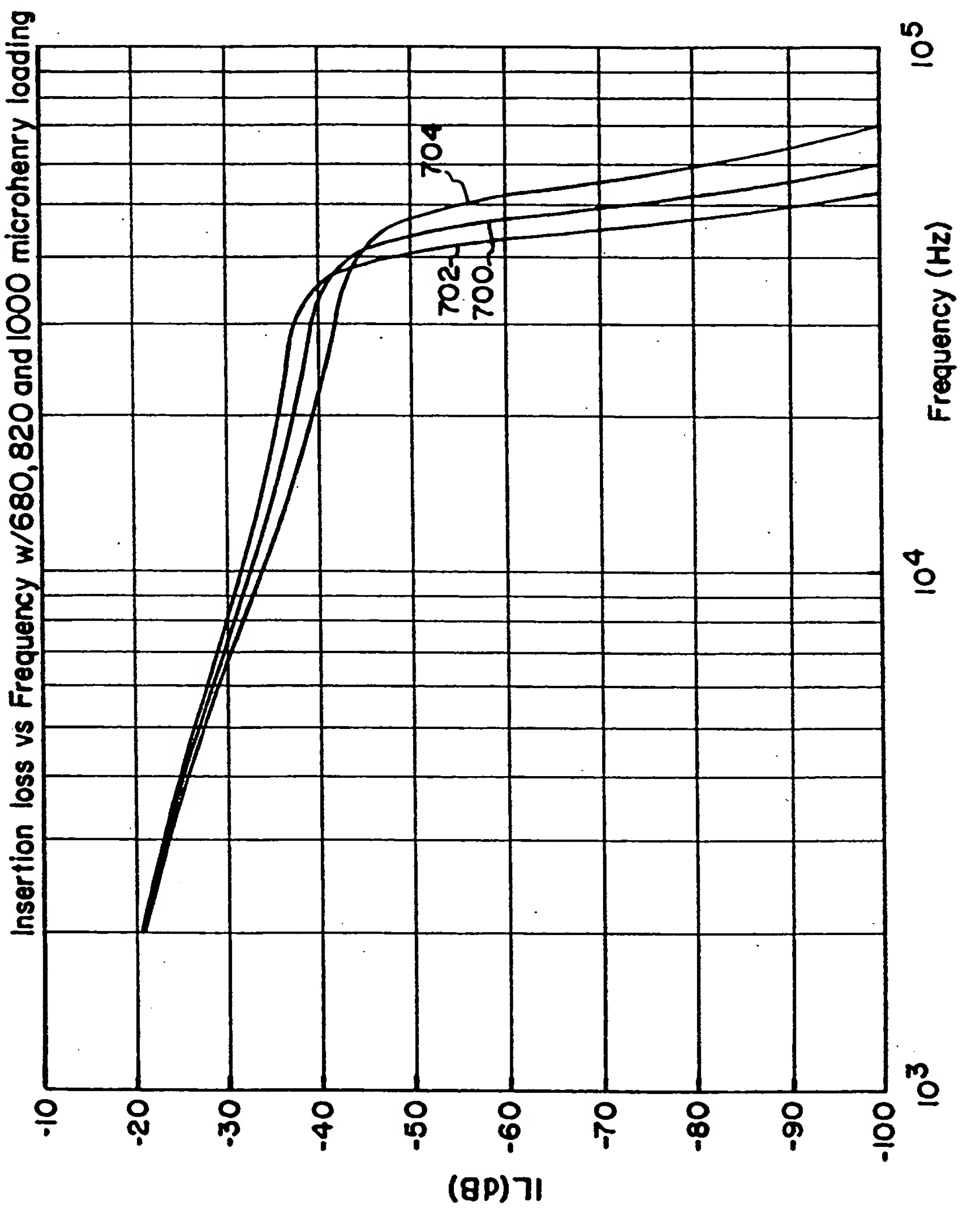
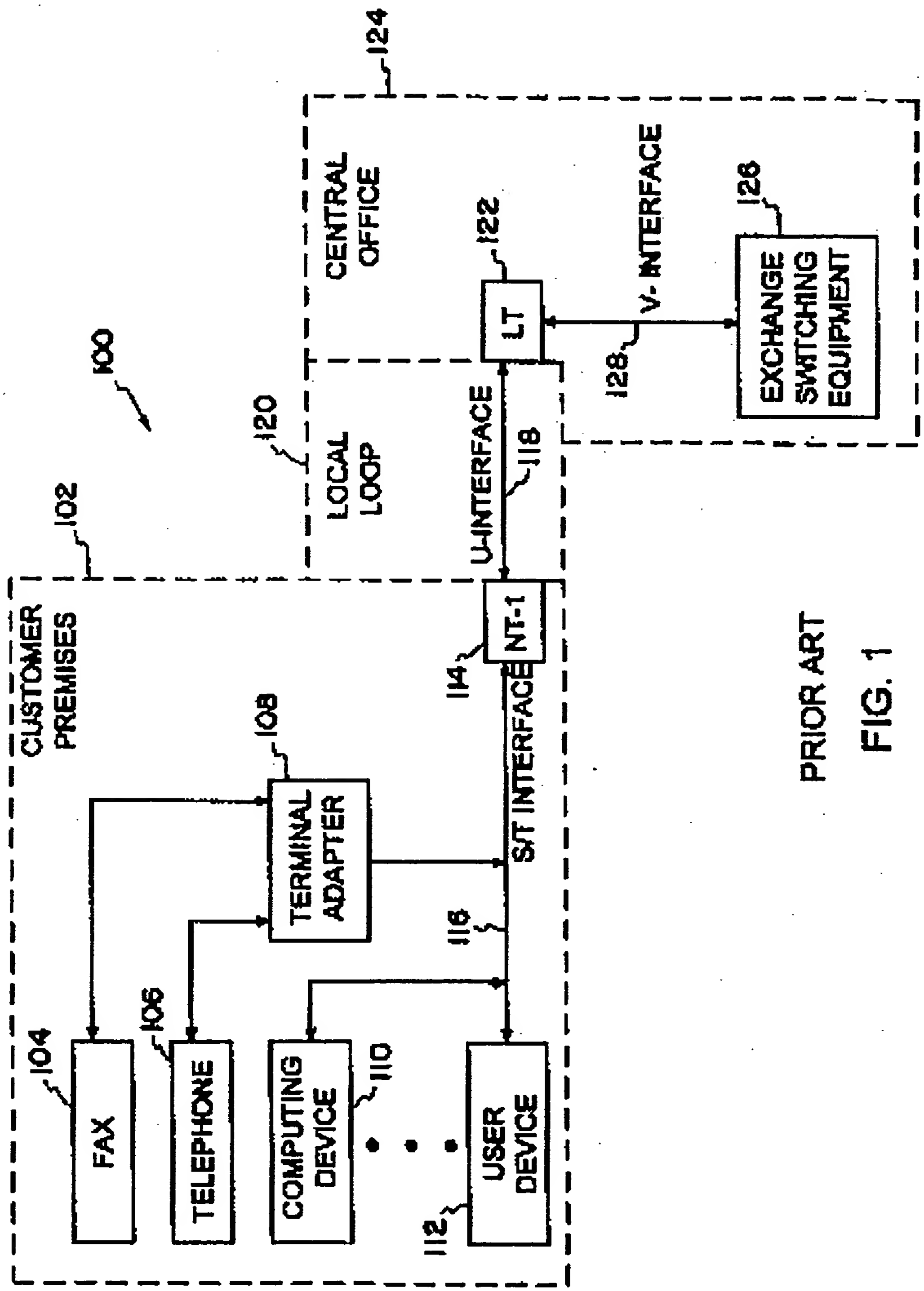

Insertion loss vs Frequency w/680, 820 and 1000 microhenry loading
IL(dB)
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
Frequency (Hz)
10^3
10^4
10^5
700
702
704

FIG. 7



PRIOR ART
FIG. 1

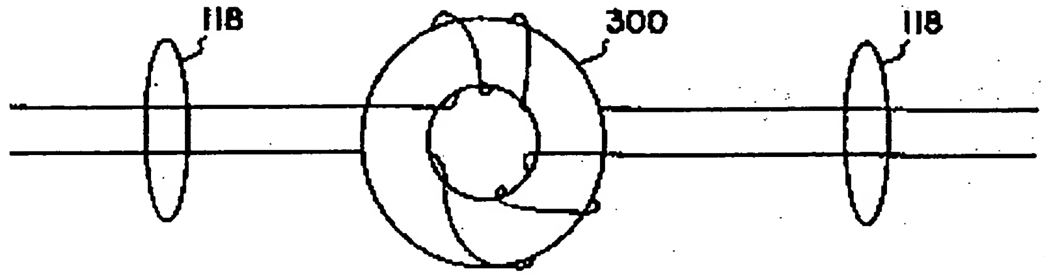


FIG. 3

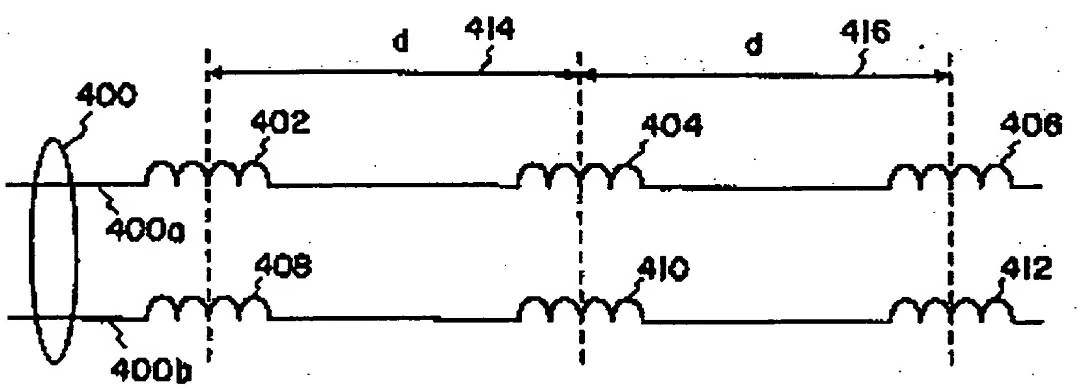


FIG. 4

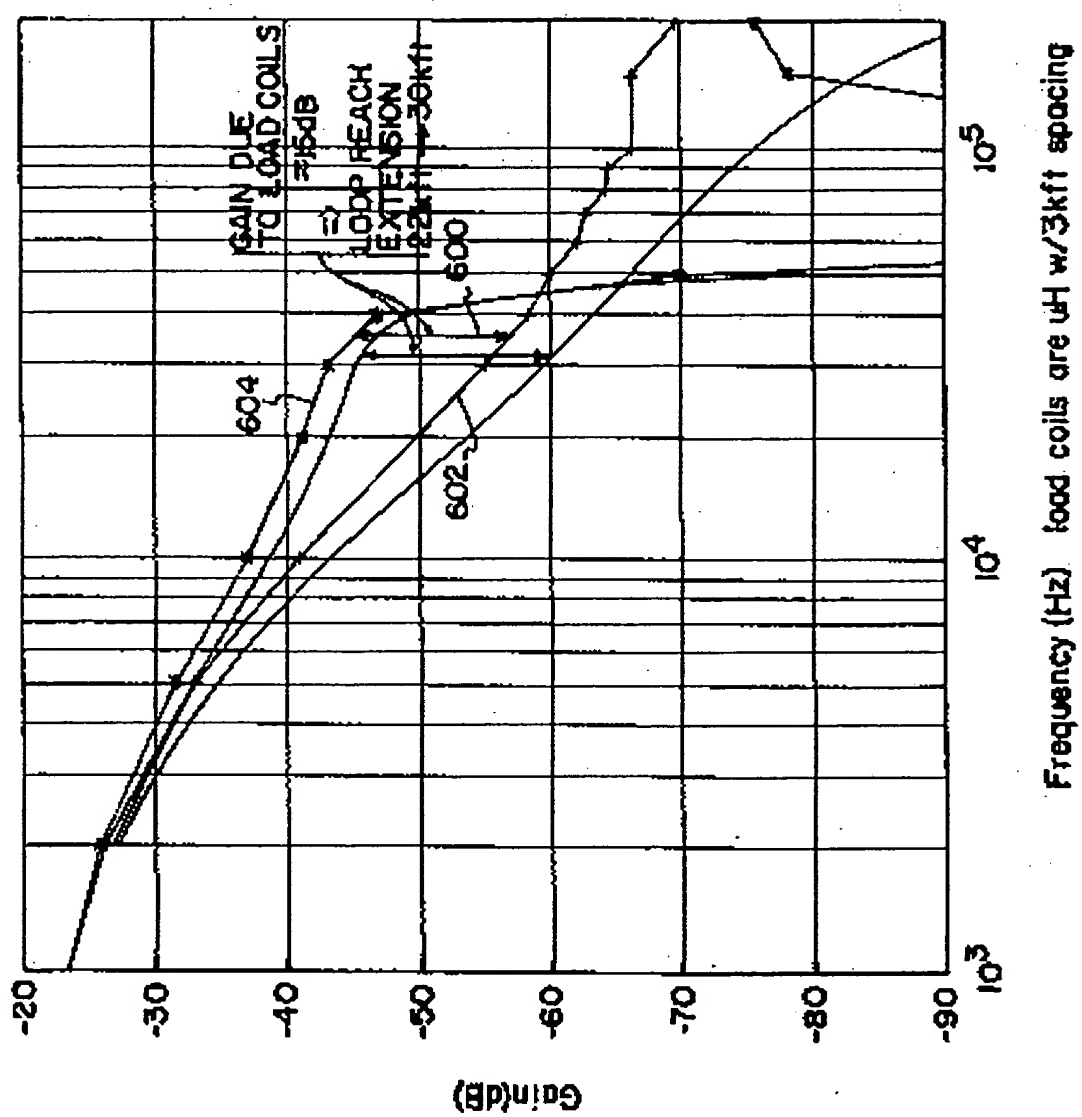

GAIN DUE
TO LOAD COILS
≈15dB
⇒
LOOP REACH
EXTENSION
600
602
604
-20
-30
-40
-50
-60
-70
-80
-90
Gain(dB)
10^3
10^4
10^5
Frequency (Hz) load coils are uH w/3kft spacing

FIG. 6

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(54) Title: SUBSCRIBER LOOP EXTENSION SYSTEM FOR ISDN BASIC RATE INTERFACES

(57) Abstract

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 98/05711

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H04Q11/04 H04B3/26

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H04Q H04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	DE 296 05 535 U (ELMEG GMBH KOMMUNIKATIONSTECHNIK) 10 July 1997 see abstract see page 8, line 5 - page 9, line 8 see figure 1	1,2,5, 11,12, 14-16
Y	US 2 362 549 A (HALE S G) 14 November 1944 see the whole document	1,2,5, 11,12, 14-16
A	GB 2 281 400 A (GPT LIMITED) 1 March 1995 see abstract see page 1, line 14-23	1,8,15, 16

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 November 1998	18/11/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Gijsels, W

CORRECTED VERSION*

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